

# Electromagnetic Launch Vehicle Fairing and Acoustic Blanket Model of Received Power using FEKO

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**Abstract:** Evaluating the impact of radio frequency transmission in vehicle fairings is important to sensitive spacecraft. This paper employs the Multilevel Fast Multipole Method (MLFMM) feature of a commercial electromagnetic tool to model the fairing electromagnetic environment in the presence of an internal transmitter. This work is an extension of the perfect electric conductor model that was used to represent the bare aluminum internal fairing cavity. This fairing model includes typical acoustic blanketing commonly used in vehicle fairings. Representative material models within FEKO were successfully used to simulate the test case.

**Keywords:** Resonant Cavity, FEKO, MLFMM

## 1. Introduction

Defining the electromagnetic environment for spacecraft can be a daunting task. Range and surrounding radio frequency (rf) emitters contribute to the environment [1]. Determining the environment inside the vehicle fairing presents further challenges. Field distribution within the cavity is influenced by resonances, accordingly simple free space equations are not applicable and full wave analysis is required for an accurate simulation. To further complicate this issue most spacecraft transmitters are in the GHz frequency range making the structures electrically large and memory requirements a constraint for many of the 3D electromagnetic simulation tools available.

In this paper a model of a vehicle fairing with layered acoustic blanketing materials is presented. The test case presented in an earlier paper is also summarized here and used for comparison data [2].

## 2. Fairing Test Fixture

### *1. Fairing Test Fixture*

A computational fluid dynamics fairing fixture was modified by lining the Lexan outer shell with industry grade aluminum foil and acoustic blankets [3]. The fixture has three sections bolted together and a metal frame outer support structure. The fixture is representative of typical launch vehicles, although at a smaller scale with a height of 2 meters and a diameter of 0.6 meters. The aluminum lined fairing fixture is shown in Fig. 1. Transmit and receive double ridge guide horns were placed at the top and bottom of the fairing fixture [4].

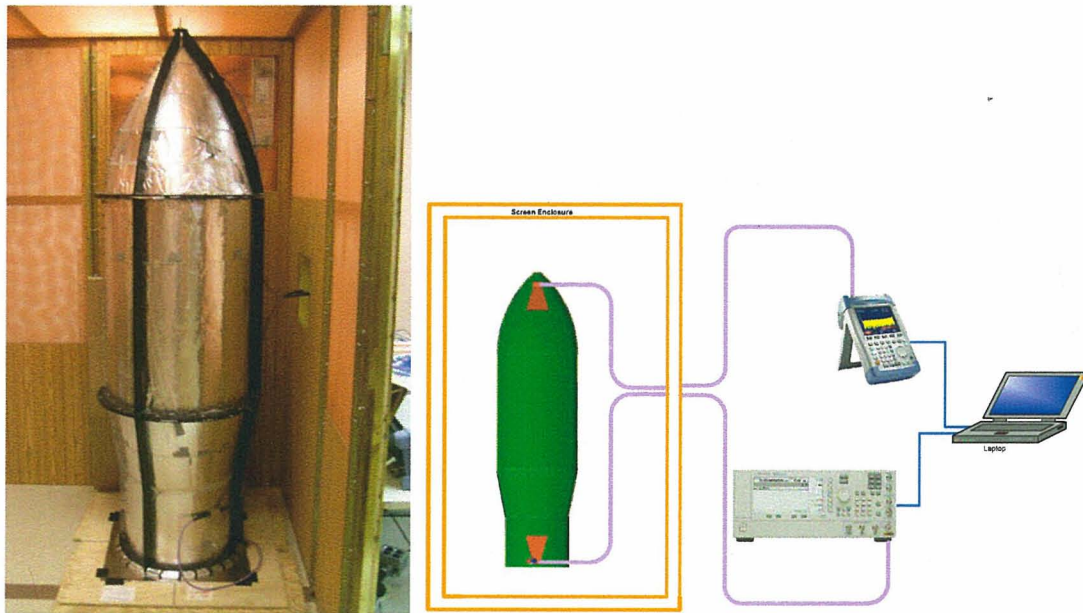


Fig. 1. Test Fixture

## II. Fairing Lining

Lining materials were added to the inside of the test fixture to simulate typical acoustic blankets inside vehicle fairings. Kapton is commonly used in space applications for its favorable thermal insulating properties. Dupont's Kapton 160XC, designed to maintain a surface resistance of 377 ohms with inherent RF absorption properties, is utilized as the outer blanket layers while standard  $\frac{1}{2}$  inch foam is used as the internal layer. Fig. 2 shows the acoustic blanketing material in the fairing fixture.

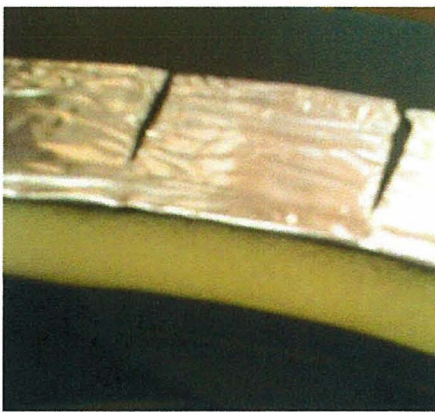


Figure 2. Acoustic Blanketing Materials

## 3. Computational Model and Simulations

A commercial Computational ElectroMagnetic software tool, EM Software Systems, FEKO is used in this study. The MLFMM feature is selected to extend the MoM technique to higher frequencies. Fig. 3 demonstrates the adequacy of this approach for an aluminum cavity represented by an impedance sheet with both MoM and MLFMM techniques. The field distribution at 1 GHz using a surface impedance of 0.015 ohms reveals excellent agreement and the received power levels between the

MLFMM and MoM models were identical. Similar results were found with FEKO's lossy metal feature which has minimal computational penalties compared to the efficiency of a perfect electric conductor (PEC). FEKO evaluates the input material properties such as permittivity and conductivity to obtain a representative impedance term, which is then added to the standard electric field integral equations used for PEC structures[5,6]. Antenna pattern models presented in [2] of the EMCO 3115 horn developed within Feko are implemented in this model. Replacing the horn model with the horn pattern affords a significant savings in computational resources. Parallelization of the FEKO code via preconditioners such as the Sparse Approximate Inverse supports solutions for detailed electrically large structures as presented here [7].

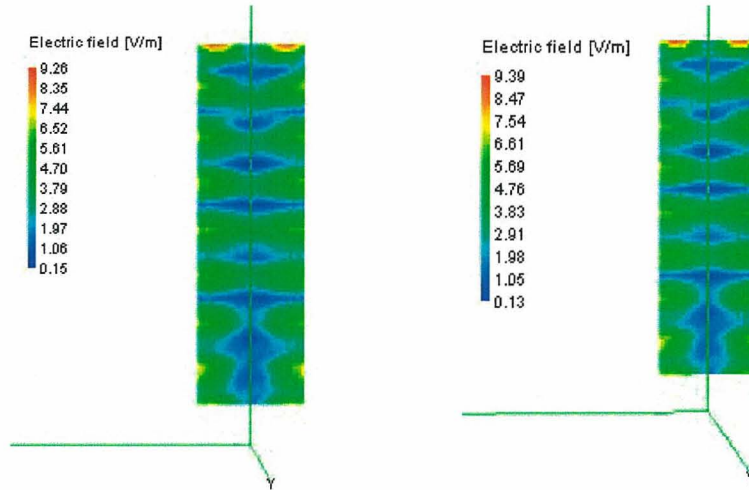


Fig. 3. Field Distribution of Aluminum Fairing – MLFMM and MoM

A combined blanketing and composite fairing structure model was presented in [8]. In this paper it is desired to represent the layers separately for test comparison. Fig. 4 shows the test fixture layers and the composite model within FEKO.



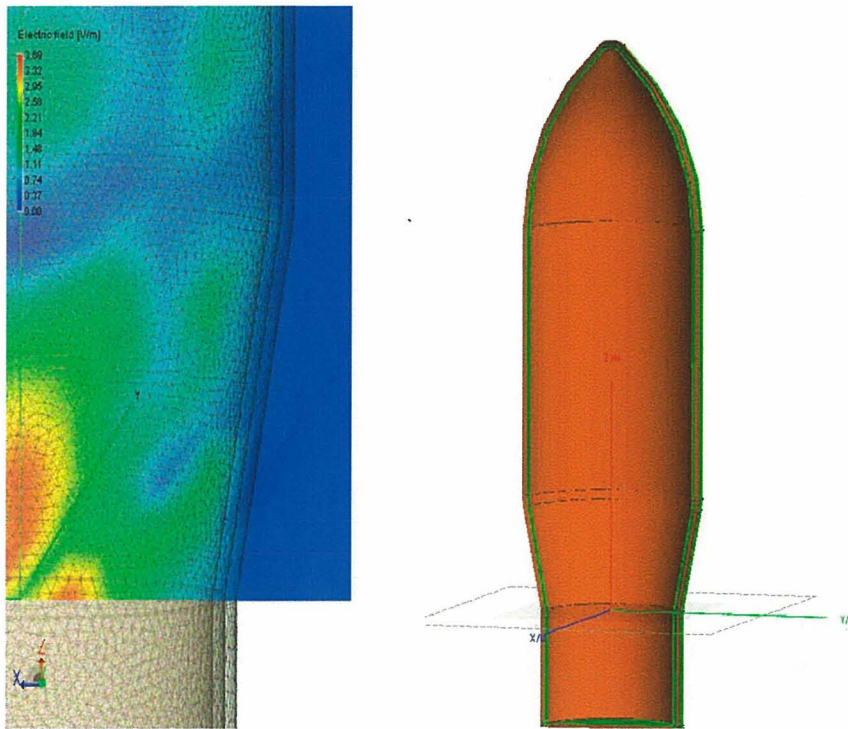


Fig. 4. FEKO model with Acoustic Blankets

The aluminum foil outer layer and acoustic blanketing layers were represented within FEKO as described below:

- The fairing outer walls were represented as a single layer lossy metal with a thickness representing the industry aluminum foil that lined the prototype fairing (0.127 mm thick).
- Kapton sheets are modeled with a surface impedance based on industry data at the model frequency.
- Gaps between the impedance sheets represent the foam layer.
- Free space is required on both sides of the impedance sheet thus a thin layer of free space is between the Kapton and aluminum.

Test to computational comparisons presented in Fig. 5 show favorable results over the frequency range considered.



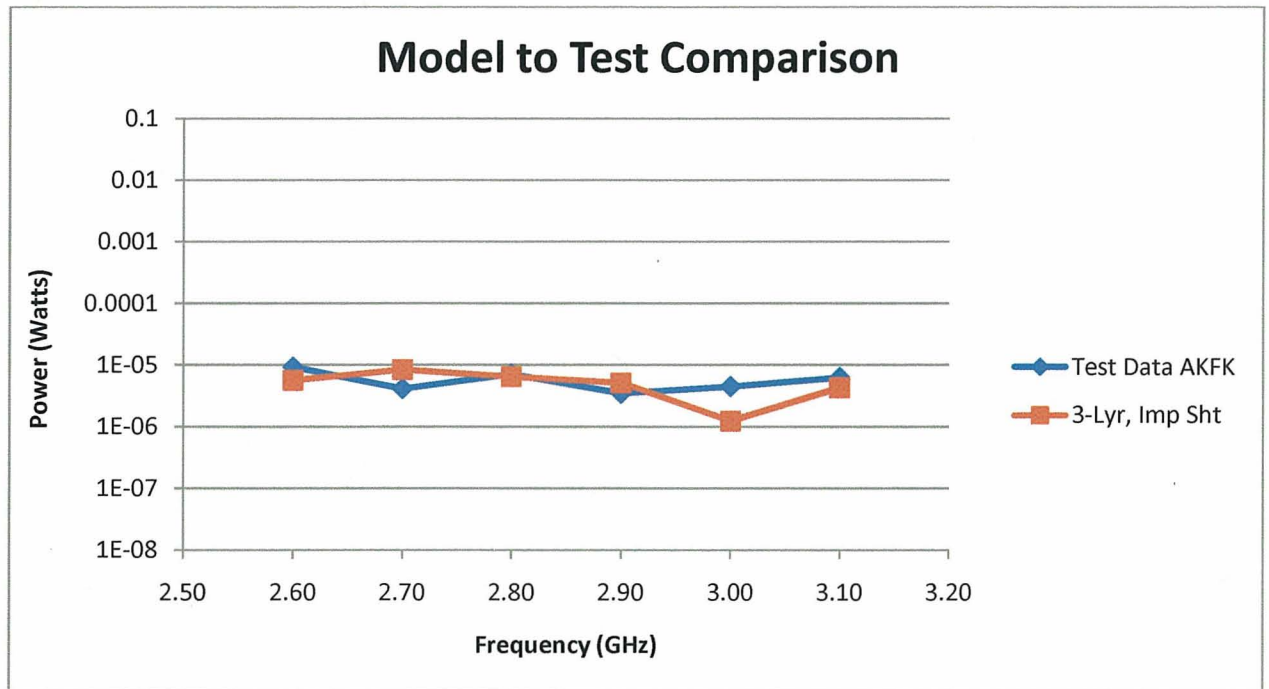


Fig. 5. Acoustic Blanket Model to Test Comparison

### 3. Conclusions

This paper shows that fairing structures with complex blanketing materials can be modeled effectively with equivalent impedance techniques in a multilayer MLFMM model using FEKO. Further expansion of this work will seek to represent cavity materials in a single mesh layer within FEKO.

### References

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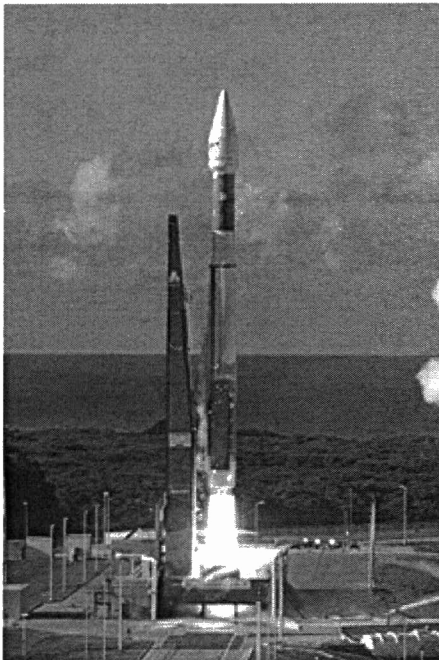
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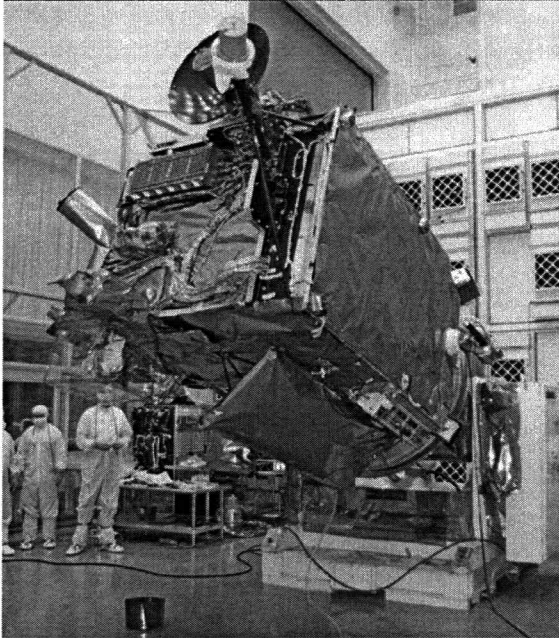
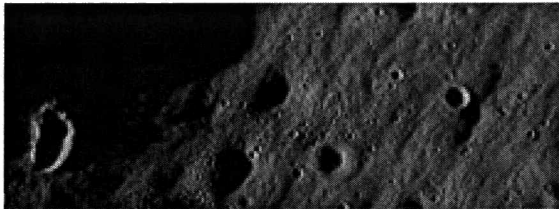
## Background- Launch Vehicles

Launch Services Program launches NASA spacecraft on Commercial expendable launch vehicles.

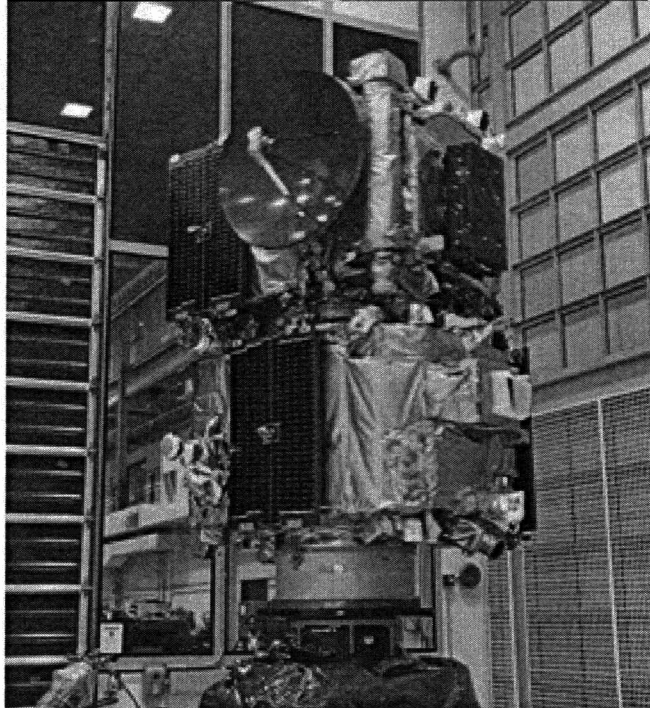
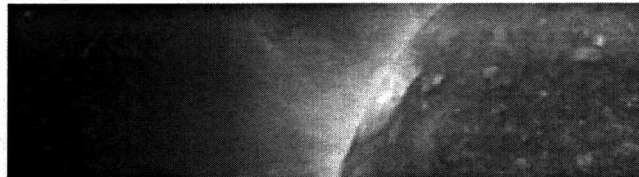


# Introduction – Space Craft

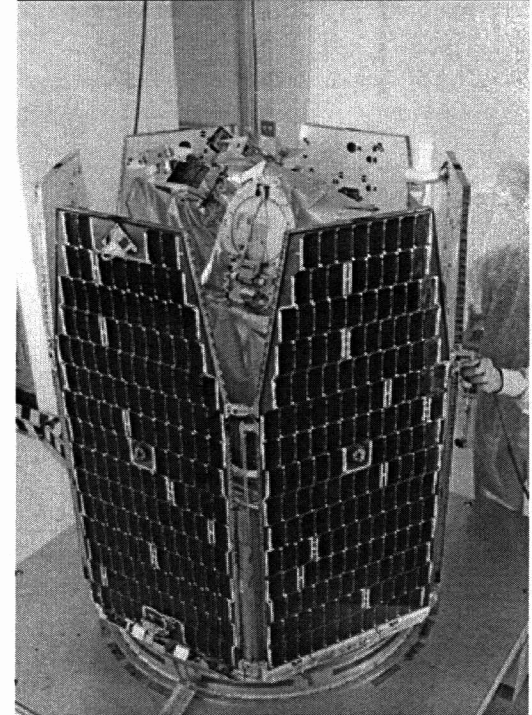
The space craft launched through LSP are widely varying in size, destination, sensitivity, and complexity.



Lunar Reconnaissance Orbiter (LRO)



Solar Terrestrial Relations Observatory (STEREO)

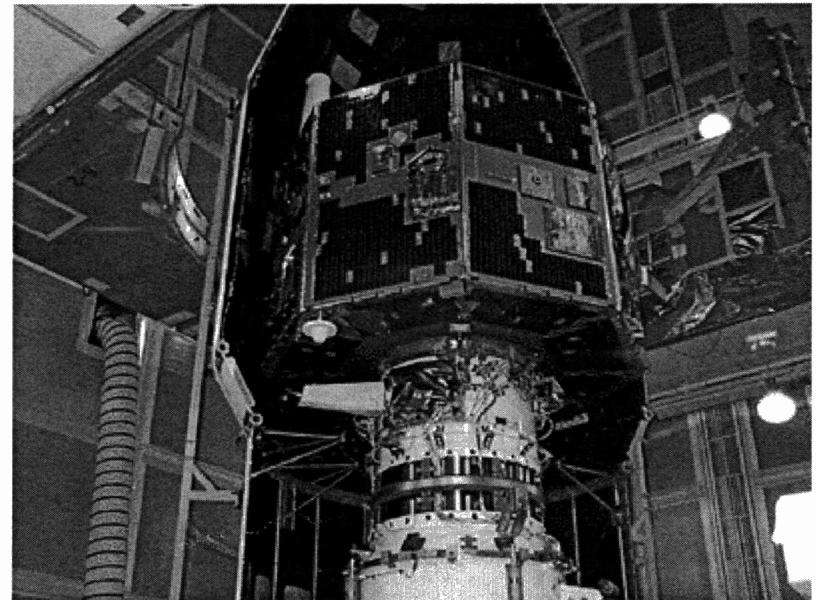


Aeronomy of Ice in the Mesosphere (AIM)

# Current Issues

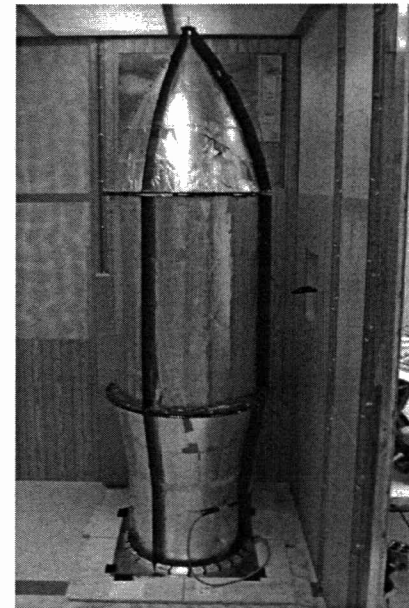
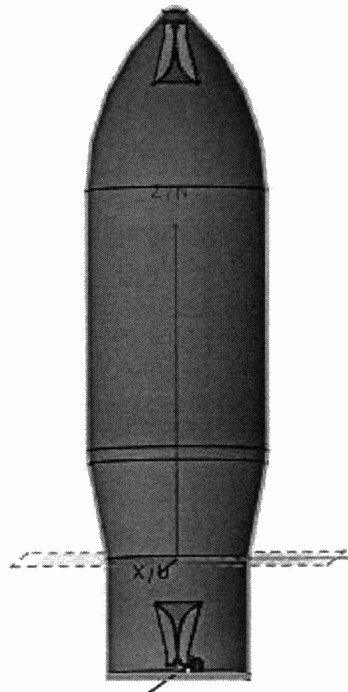
## Fairing RF Environment

- Transmission inside Vehicle Fairing
  - Inhibits (reliability)
  - GHz frequencies
  - Computationally Intensive (large cavity and small wavelength)
  - Dielectric layers can be very thin
  - Reradiation, RF windows
- Each mission has unique parameters
  - Fairing Volume
  - Fairing Material
  - Fairing Blankets
  - Payload Volume
  - Payload Materials



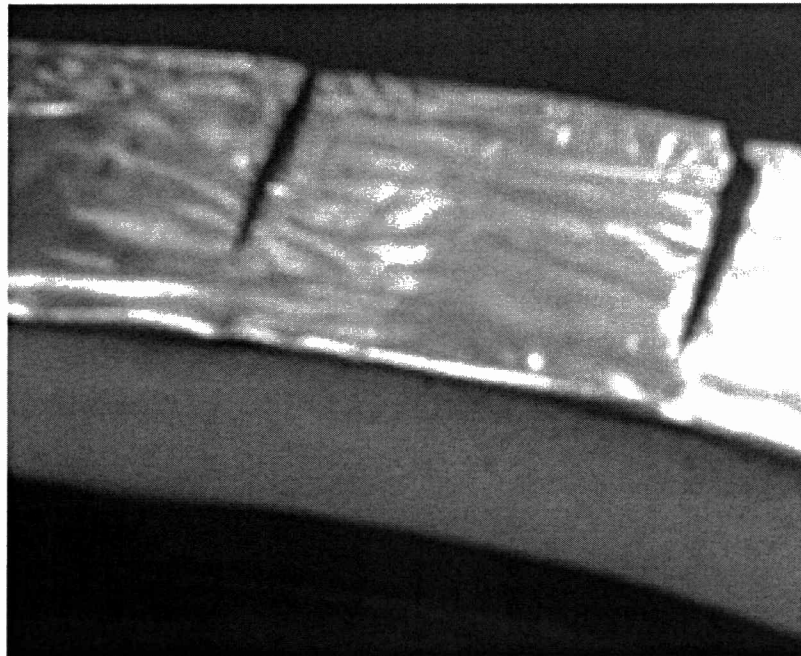


# Fairing FEKO Model and Test Fixture



Test fixture with CAD model  
0.6 m X 2m  
(about ½ to 1/10 of full vehicle scale)

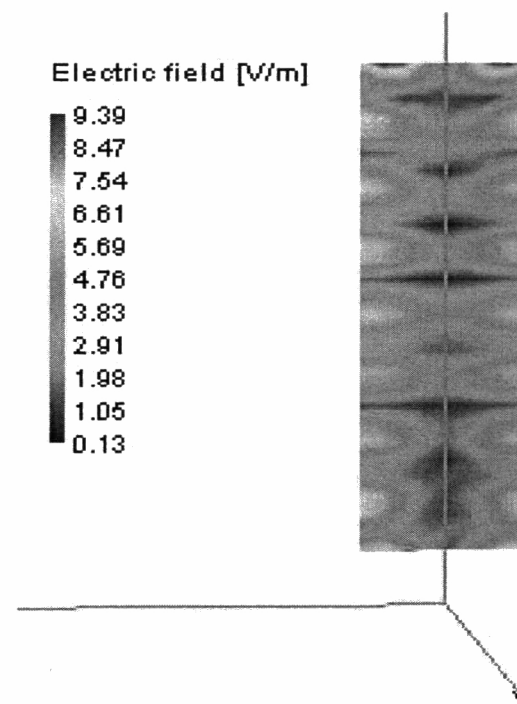
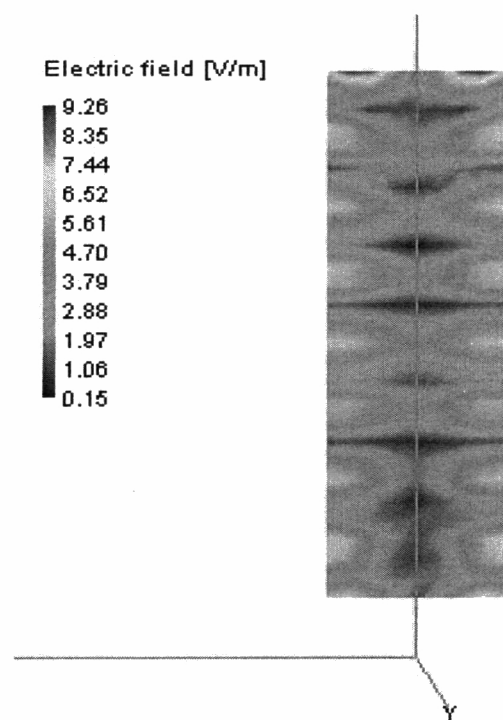
# Blanket layers



- FEKO Implementation of Impedance Sheet

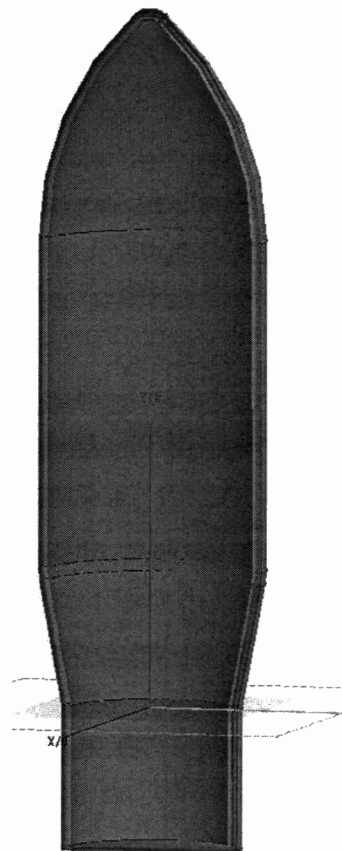
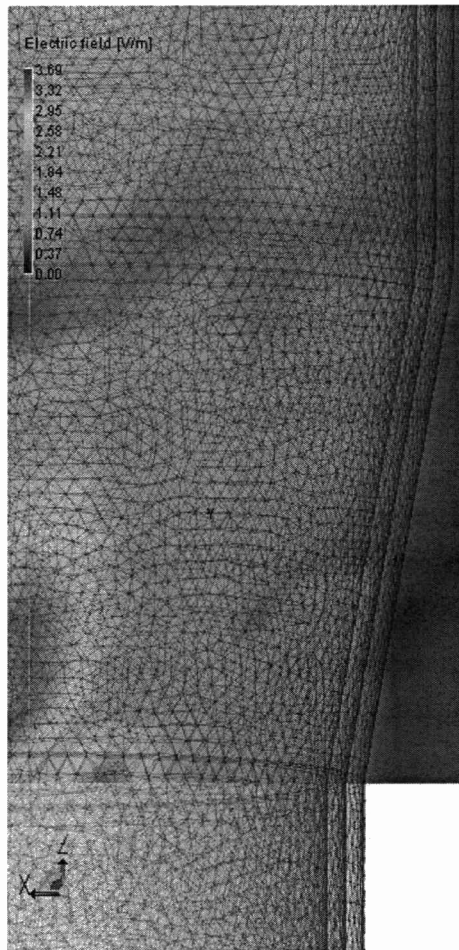
$$E_{s,tan} - Z_s J_s = -E_{i,tan}$$

# MOM/MLFMM Field Distribution Comparison at 1 GHz





# FEKO 3 Layer Blanket in Metal Fairing Model

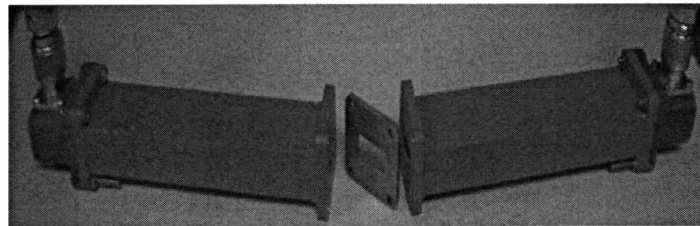


- The aluminum foil outer layer and acoustic blanketing layers were represented within FEKO as described below:
- The fairing outer walls were represented as a single layer lossy metal with a thickness representing the industry aluminum foil that lined the prototype fairing (0.127 mm thick).
- Kapton sheets are modeled with a surface impedance based on industry data at the model frequency.
- Gaps between the impedance sheets represent the foam layer.
- Free space is required on both sides of the impedance sheet thus a thin layer of free space is between the Kapton and aluminum.

Fig. 4. FEKO model with acoustic blankets.

# Equivalent Layer Techniques

- Metal with Coating
  - S parameters measured to predict the equivalent complex permittivity and permeability of the layered media (NRW Technique).



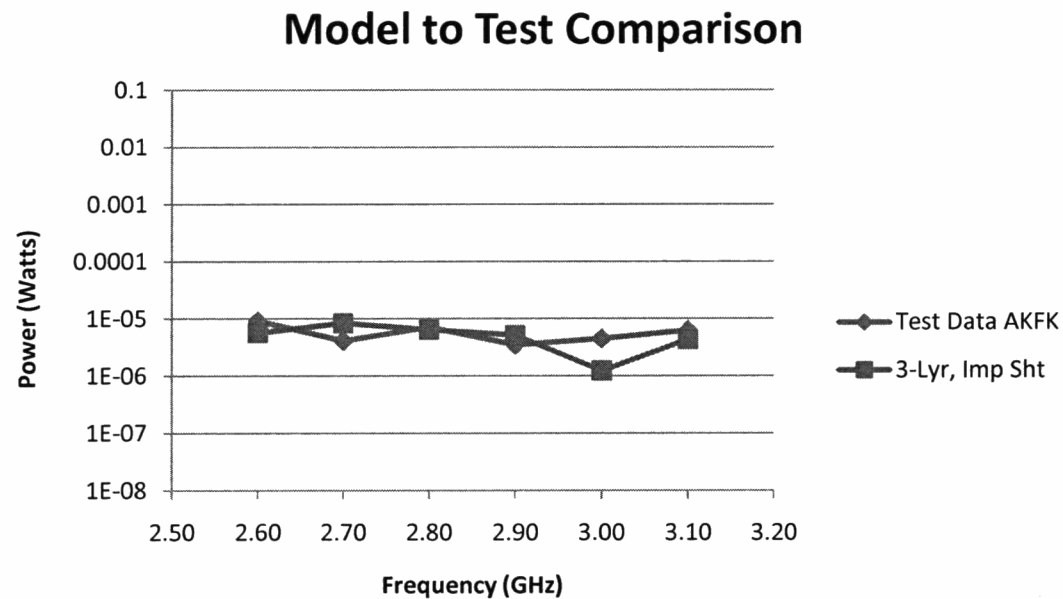
- Heritage perpendicular incidence layer combination implemented with Impedance Sheet
- Impedance Sheet with Al coating

# Memory/Run Time Comparison

Method	Freq (GHz)	# unknowns	CPU Time/process (hrs)	CPU Time All processes (hrs)	Peak Mem All Processes (GB)
MoM 1 layer	2.6	124,377	21.2	339	115
MLFMM 3 layer	2.6	372,622	3.9	60.9	10
MLFMM 1 layer	2.6	124,377	0.57	4.5	1.4
MLFMM 3 layer	10	4,775,942	6.652	106.4	76.4
MLFMM 1 layer	10	1,750,158	3	49.6	27
P0 1 layer	10	1,114,263	0.43	6.9	4.9

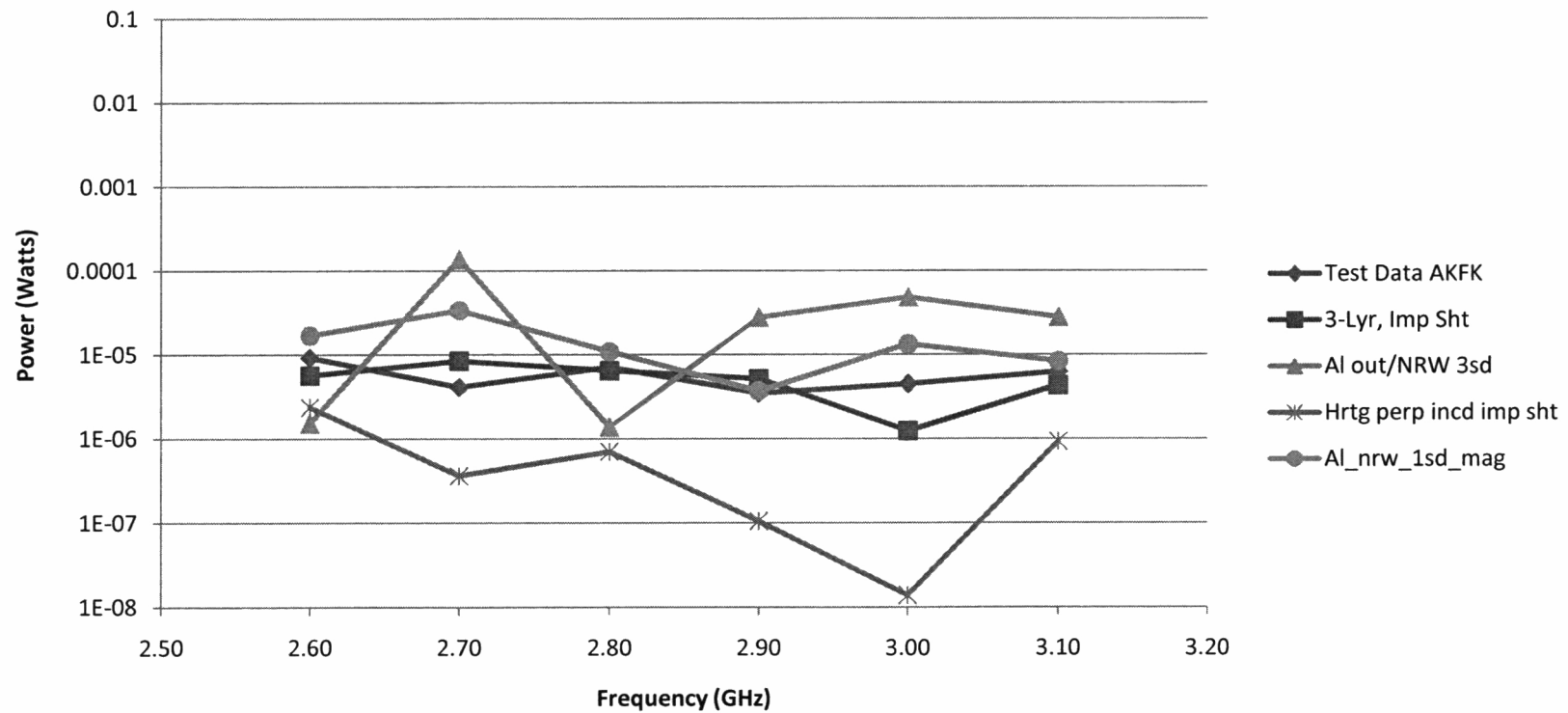


# Acoustic blanket fairing model to test comparison



# Equivalent Layer Techniques

## Model to Test Comparison



## Conclusions

- Internal Fairing Transmitter Issue was described
- A scaled fairing model with blankets has been successfully modeled within FEKO at S-Band (3 Layer Model).
- A 1 layer model has been demonstrated using measured.
- Future Work is planned to further evaluate:
  - Typical Spacecraft Loading Effect
  - Composite Structures
    - Multiple field measurement points
    - Omnidirectional monopole antennas